

Experimental Investigation on Behavior of Friction Materials in Brake Liners

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Abstract

Brake linings have complex microstructure and consists of different components. The purpose of this research is to optimize the use of brake liner frictional materials with new formulation incorporating micaceous iron oxide and calcium carbonate as a filler material and comparison of improvement in frictional value with other filler materials. This new formulation was tested under various operating conditions with a chase machine friction testing rig. The friction test rig was programmed with different test loops to perform test as per SAE J661. The average coefficient of friction, coefficient of friction with changing speed, temperature and load, thickness loss and weight loss were accounted. Formulation exhibits better thermal stability and wear resistance to the latter.

Keywords: Brake liners; Chase machine; Filler materials; Mix formulation; Wear characteristic

Introduction

The brake friction materials play an important role in the braking system. During breaking it convert the kinetic energy to thermal energy by friction due to the braking process. In this instinct the brake liners should poses the constant coefficient of friction at any operating conditions. Apart from this, it should also possess various resistance to heat and water, low wear rate and high thermal stability, but this is impossible to achieve all this in practical conditions. For this reason, the research investigated the filler materials like calcium carbonate, micaceous iron oxide with the abrasive and binders to give a better structural reinforcement. This filler material is low in cost for the manufacturing process and only less quantity is required compared to filler quantity used earlier. Followed by, this new formulation is tested for coefficient of friction. In which various stages including baseline test, fade, and wear and recovery test are performed with friction testing machine. From the measurements, the analysis was carried out to check the behavior of friction in brake lining comparing with the regular formulation.

Related Works

Tsang studied testing of various friction materials with the aid of chase testing machine and inertia brake dynamometers testing. The results from both test method was compared which resulted inconsistent [1]. Peter surveyed the brake materials and additives used for the formulation of the commercial brake and to indicate their typical properties prepared for U.S Department of energy [2]. Sterle and Klob studied the brake friction materials and analyzed the wear the characteristics of the materials especially with organic materials in brake [3]. Herring studied and developed a mechanism for the fade in the organic brake linings, which resulted in high frictional stability of the brake liner were improved at very high speed [4]. Rukiye and Nurettin described the tribological parameter such as wear resistance and frictional stability depending upon the test temperature and number of braking involved [5,6].

Experimental Setup

Sensors, load cell, pressure controller and blower

The main drive to the test drum is provided by 10 HP motor

through drive pulley and belt arrangement to give a rotational speed of 417 rpm $\pm$ 5%. The 1" square sample piece is mounted inside the drum with easily retractable arms. The 11" (279 mm) inside diameter brake drum is made of cast iron and have pearlitic grain structure. The drum will have average Brinell hardness between 179 and 229. Heating of the drum is by electrical heaters and temperature control is achieved by connecting a centrifugal blower to the control circuit. These are the setup that can be seen in the Figure 1.

An air cylinder, through a pressure regulator the vertical 150 lb load is applied. The resulting friction force and the applied vertical load are measured by load cells. The Drum temperature is measured by IR thermometer. The speed of rotation of drum is measured using rpm speed sensor. Along with a SSR (solid state relay) is provided for the entire heater coils (A1, A2 and A3), blower exhaust fan, solenoid-1 and solenoid -2 shown in the Figure 2 respectively. RS232 port inputs the values into the picKit processor with loop controlled operation, the results are manipulated. All the major parameters like applied load, friction force, Drum temperature and drum RPM etc are recorded.

Testing Program

Operating conditions

For this test desired measuring points are needed and followed by that various operating conditions are chosen according to the requirement,

1. The compressor is turned on and the pressure is set by adjusting the pressure regulator screw at around 10-12 psi, so that a load of 150 lb (68 kg $\pm$ 10%) is applied on the sample.

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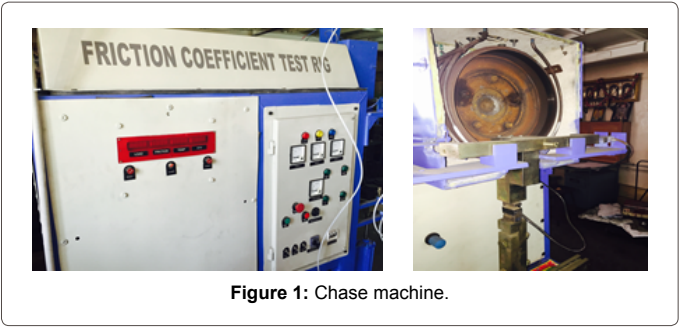


Figure 1: Chase machine.

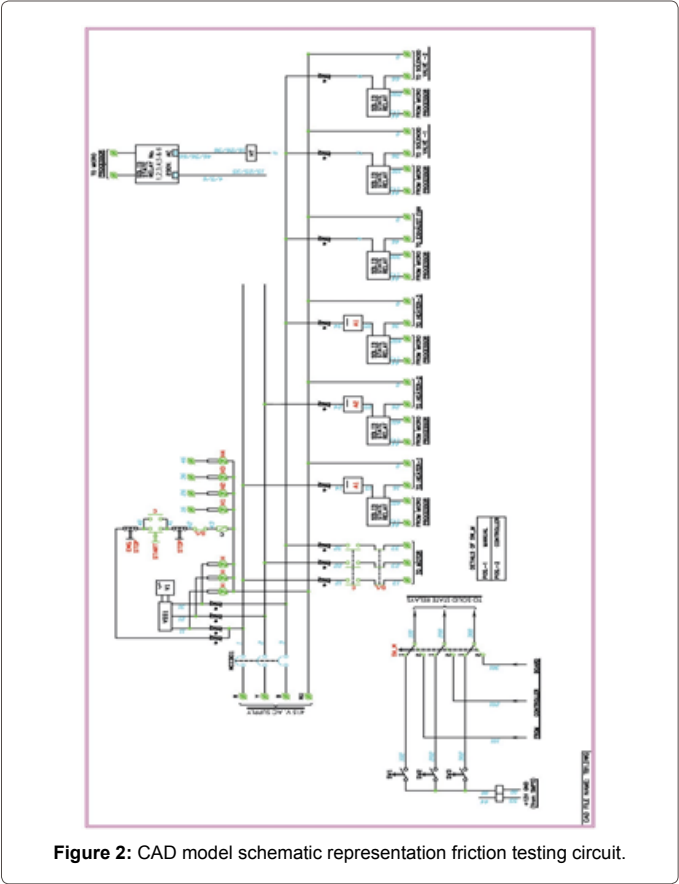


Figure 2: CAD model schematic representation friction testing circuit.

2. The motor is switched on from the control panel shown in the Figure 1 and the frequency setting on the variable frequency distributor made around 18.25 Hz. This will give 420 rev/min on the brake drum end.

Friction testing stages with description

Base line run: This stage runs continuously for 10 seconds brake ON and followed by 20 seconds brake OFF at 150 lb/sq.inch load, 417 rev/min of the test drum for 20 allocations. The test starts at 93°C (200°F) and maintains temperature of 200°F throughout the test (+/- 10%).

First fade run: After baseline run, this stage runs with continuous drag at 150 lb load with heater ON and cooler (blower) is turned OFF. The test starts the operation at 93°C and runs for either 10 minutes or until the temperature reaches 550°F. Whichever occurs first, the coefficient of friction is recorded on drum temperature at

50°F temperature interval. The time required to reach 550°F are also recorded.

First recovery run: Immediately on the completion of the first fade run, the heater turns OFF automatically and then cooler turns ON. In this instant it records 10 seconds (load) allocations at each 37.8°C (100°F) interval during from 500°F to 200°F.

Wear measurement: Once the recovery stage gets completed, the wear stage runs for 20 sec brake ON and 10 sec brake OFF condition. A constant load of 150 lb pressure and 417 rev/min is maintained for 20 allocations. The test starts at drum temperature of 400°F (+/- 5 %) and maintain the same temperature throughout.

Second fade run: On the completion of the second wear test. Cool drum to 200°F and then run continuously brake drag at 150 lb pressure 417 rev/min. With heater ON and cooling OFF, start at 200°F and run for either 10 minutes or until temperature raises to 650°F. which ever occurs first take simultaneous reading of friction and temperature at 50°F interval record time to reach 650°F.

Second recovery run: Immediately on completion of the second fade turn OFF heater and turn ON cooling, then make 10 seconds brake allocations at each 100°F interval during cooling from 600°F to 200°F repeat second base line run as first run.

Formulation Involved

To analyze the role of filler materials in coefficient of friction value improvement, two samples were prepared from formulation involved with the change in filler materials (the formulations are shown in Tables 1 and 2. The purpose of adding filler materials is to improve the coefficient of friction. The function of filler with resin will enhance

Sl.No	Material	% in the formula
1.	Friction dust	8.0
2.	Barytes	7.0
3.	Resin	22.0
4.	Graphite	24.0
5.	Steel fiber	18.0
6.	Iron powder	4.0
7.	Alumina	1.0
8.	Micaceous iron oxide	8.0
9.	Marble dust	4.0
10.	Tire dust	3.0
11.	Friction dust black	1.0
Total		100.0

Table 1: Sample A formulation.

Sl.No	Material	% in the formula
1.	Friction dust	8.0
2.	Barytes	7.0
3.	Resin	22.0
4.	Graphite	24.0
5.	Steel fiber	18.0
6.	Iron powder	4.0
7.	Alumina	1.0
8.	Calcium Carbonate	8.0
9.	Marble dust	4.0
10.	Tire dust	3.0
11.	Friction dust black	1.0
Total		100.0

Table 2: Sample B formulation.

the structure reinforcement of the brake lining composition. Barium Sulphate (barytes) is used as additional filler materials in both the formulation. As the micaceous iron oxide are basically fine particles with high surface area. An additional quantity of resin was added to produce perfect bond. In the first sample micaceous iron oxide is incorporated and in the latter with calcium carbonate respectively. These samples were made in size of 1" square piece and tested shown in Figure 3.

Results and Analysis

Composite materials are tested under various operating cycles. From the results it is inferred that in sample B the coefficient of friction is not stable at high temperature compared to the sample A. From the fade and recovery stage it clearly shows that micaceous iron oxide properties reveal better wear resistance. The coefficient of friction is 7% increase in this case compared to the calcium carbonate added sample. However there are some problems when adding conventional micaceous iron oxide caused mainly by variations in quality, which lead to unreliable results. Noise levels were reduced during test cycles performed in sample A. The commercial brake liner friction coefficient is about 0.55 and less. With the addition of appropriate filler additive friction materials, the new formulation improvement of coefficient of friction is around 9% to the commercial brake liners. The weight loss and thickness loss calculated for both the samples, the wear rate is high for the sample B and in the case of sample A it is less due to density is higher in number. The availability of calcium carbonate is better alternative to the barytes, which is less expensive. In order to improve the formulation still higher, the organic materials added should be reduced. Overall this formulation has significantly improved

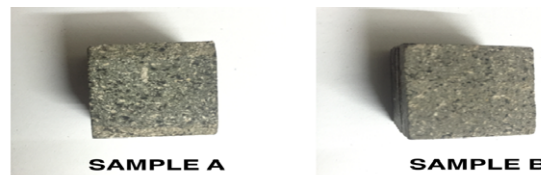


Figure 3: Test samples A and B.

the important properties of brake liner friction materials like heat dissipation, better reinforcement of the composition and also improved the coefficient of friction with reduced noise level.

In Figure 4, At the ambient temperature the baseline stage however shows low coefficient of friction but after 6 applications. Both the samples coefficient of friction increases consistently. Then at 17th application sample B falls down in coefficient of friction whereas sample A the coefficient of friction value is quite constant

In the Table 3 the baseline 1 and 2 throughout the 20 allocations of constant loading and maintain a temperature of 200°F. The sample A in both the cases show higher friction coefficient than the sample B. Also the value drops at last 5 applications for sample B but the former one is gradually increasing.

From the Figure 5, both the samples curve steeply increases. It can be inferred that material behaves good consistently up to 16 applications. But sample A there is no drop in consistency, it peaks upto the scale.

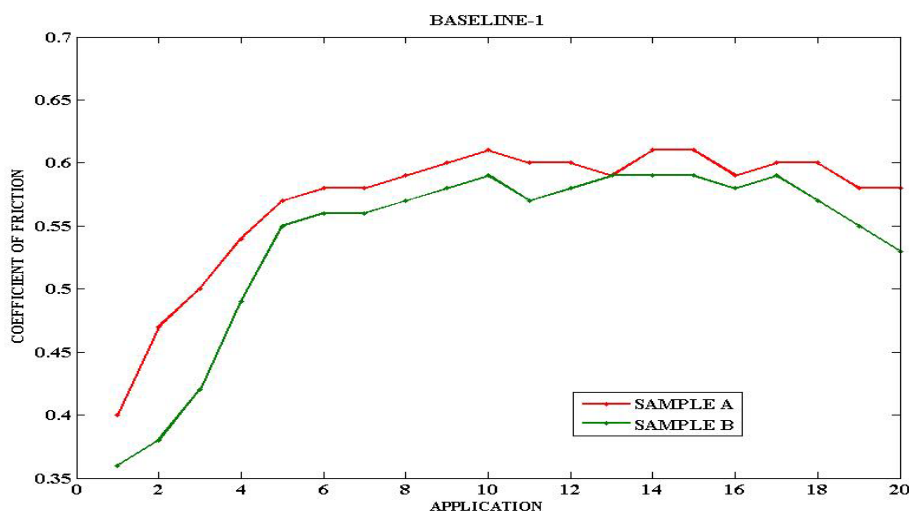


Figure 4: Plot comparison between the samples in baseline-1.

Baseline-1							Baseline-2					
	Temp (° F)		Force-F		μ		Temp (° F)		Force-F		μ	
	Samples						Samples					
	A	B	A	B	A	B	A	B	A	B	A	B
1	213.2	215.8	2.0	0.9	0.40	0.36	210.2	209.5	16.0	14.8	0.45	0.43
5	205.4	203.5	18.0	17.2	0.54	0.54	208.3	195.6	17.5	17.6	0.56	0.53
10	218.4	216.3	17.5	16.7	0.61	0.59	215.7	204.8	17.5	16.5	0.55	0.51
15	210.5	207.5	18.5	18.7	0.61	0.59	209.4	223.5	17.5	17.4	0.59	0.58
20	208.1	205.1	19.0	18.3	0.58	0.53	212.6	219.6	17.7	17.6	0.61	0.56

Table 3: Baseline stage 1 and 2.

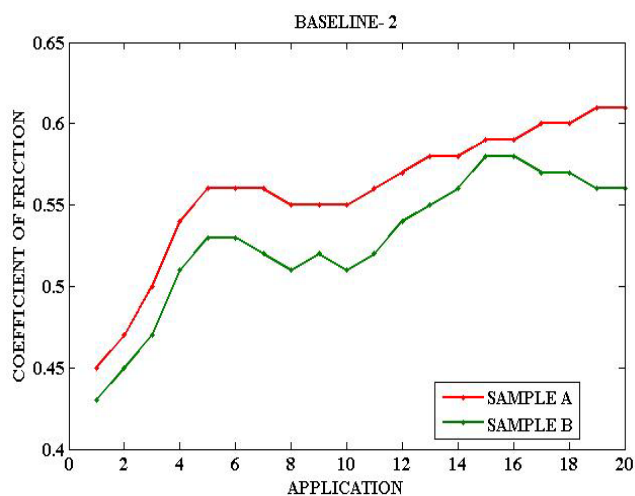


Figure 5: Plot comparison between the samples in baseline-2.

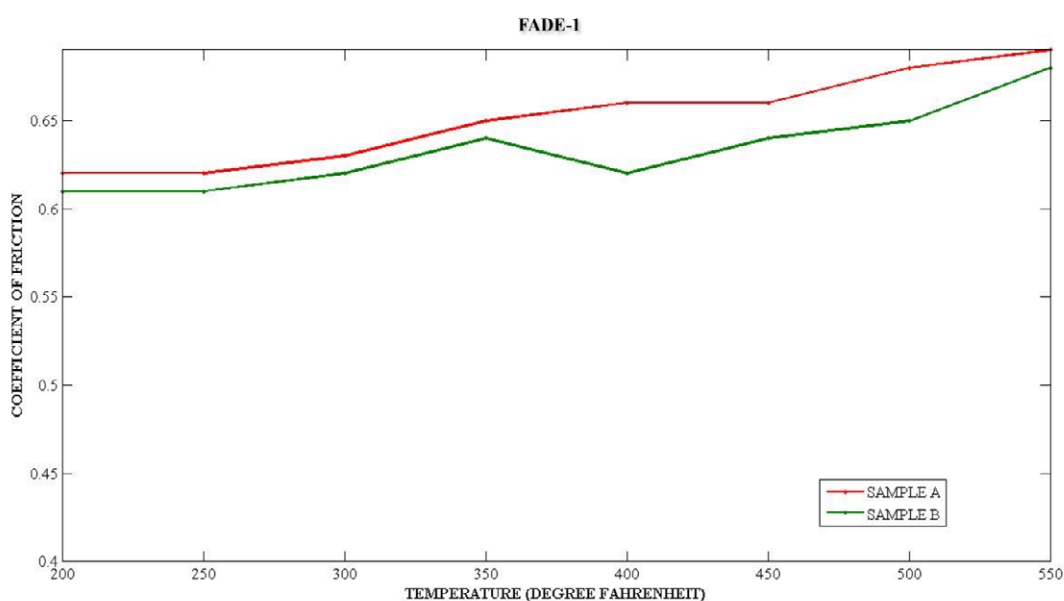


Figure 6: Plot comparison between the samples in fade-1.

It is evident from Figure 6, the coefficient of friction is consistent and steps up considerably. But it is inferred that sample B drops in coefficient of friction after 350°F whereas sample A shows consistent progress, actually the curve gets increasing in coefficient of friction after 400°F.

The transient temperature behavior of both sample were significantly same at 390°F. But just in this case, it falls down and somehow the physical property of material is good at higher range of temperature for sample B. The former performs consistent than latter shown in Figure 7.

The temperature is consistently increased 50°F for every loading condition and time is recorded for each interval temperature reaching time. It is inferred that sample A that frictional value increases at a gradual scale, however sample B drops at intermediate temperature.

At higher temperature both samples result in better frictional values shown in the Table 4.

From the Figure 8, it clearly depicts that sample A friction characteristic behavior changes at 400°F. In this recovery stage the sample B deviates a lot in coefficient of friction with changing temperature. In Figure 9, both the samples correspond to same coefficient of friction at the intermediate temperature. But the sample A is strictly linear and sample B drops at 300°F, then it regains its coefficient of friction after 400°F. This sample B shows higher wear rate but it shows quite better wear rate at higher range of temperature. From the Table 5 it clearly depicts that the frictional values gradually drops down for both the samples at a considerable rate but the sample A recovers earlier corresponding to the sample B.

Wear characteristics of both the samples show similar result shown

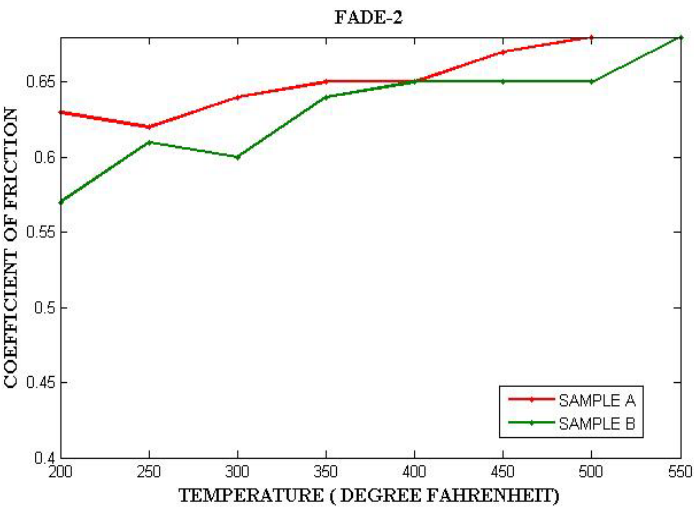


Figure 7: Plot comparison between the samples in fade-2.

Temp (° F)	Fade-1						Fade-2					
	Time(sec)		Force-F		μ		Time(sec)		Force-F		μ	
	Samples						Samples					
	A	B	A	B	A	B	A	B	A	B	A	B
200	0	0	19.4	19.2	0.62	0.61	0	0	19.5	19.4	0.63	0.57
250	15	15	19.2	19.2	0.62	0.61	17	16	19.3	19.0	0.62	0.61
300	30	30	19.2	19.0	0.63	0.62	32	31	19.3	19.4	0.64	0.60
350	52	49	19.3	18.8	0.65	0.64	49	50	19.6	19.6	0.65	0.64
400	70	73	19.4	19.0	0.66	0.62	74	75	19.2	19.3	0.65	0.65
450	107	104	19.6	19.2	0.66	0.64	103	107	19.6	19.2	0.67	0.65
500	160	158	19.5	19.3	0.68	0.65	158	159	19.2	19.6	0.68	0.65
550	281	279	19.8	20.0	0.69	0.68	280	268	20.0	20.0	0.68	0.68

Table 4: Fade stages 1 and 2.

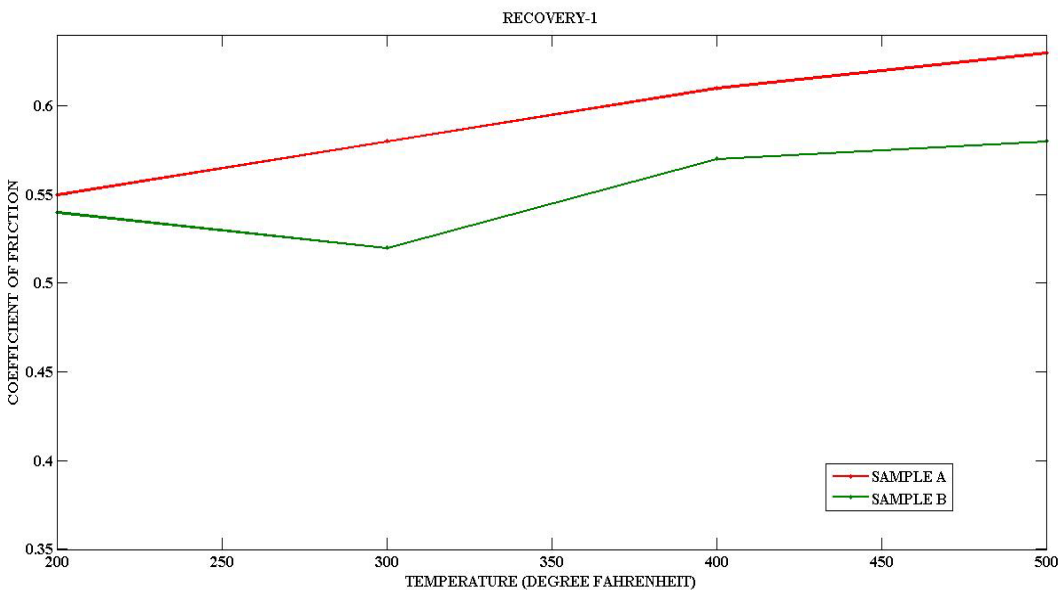


Figure 8: Plot comparison between the samples in recovery-1.

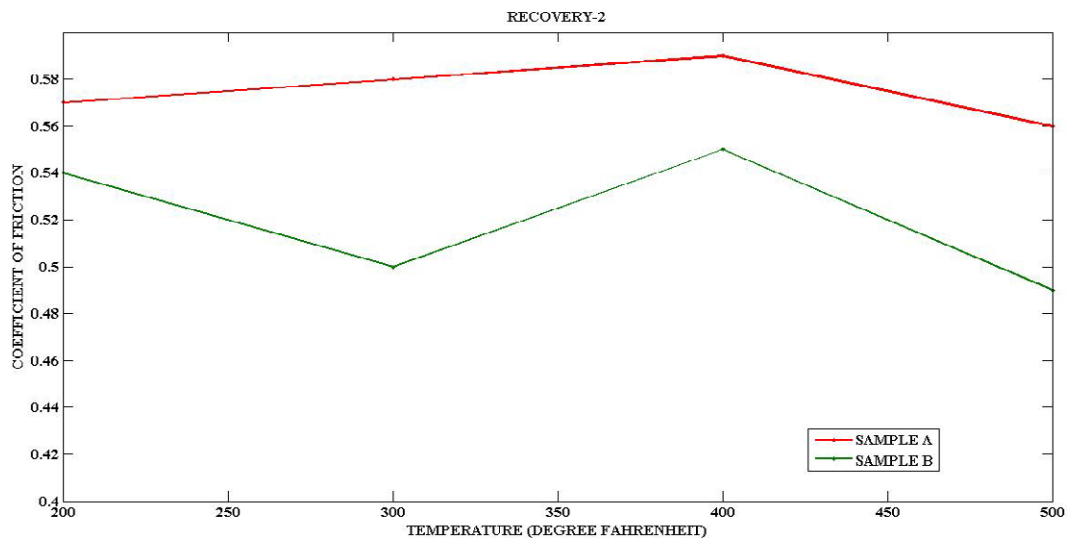


Figure 9: Plot comparison between the samples in recovery-2.

Recovery-1					Recovery-2			
Temp (° F)	Force-F		μ		Force-F		μ	
	Samples		Samples		Samples		Samples	
	A	B	A	B	A	B	A	B
500	19.00	18.70	0.63	0.58	17.60	15.70	0.56	0.49
400	18.90	18.40	0.61	0.57	18.00	17.40	0.59	0.55
300	18.30	17.7	0.58	0.52	17.80	16.90	0.58	0.50
200	18.00	17.9	0.55	0.54	17.50	17.80	0.57	0.54

Table 5: Recovery stages 1 and 2.

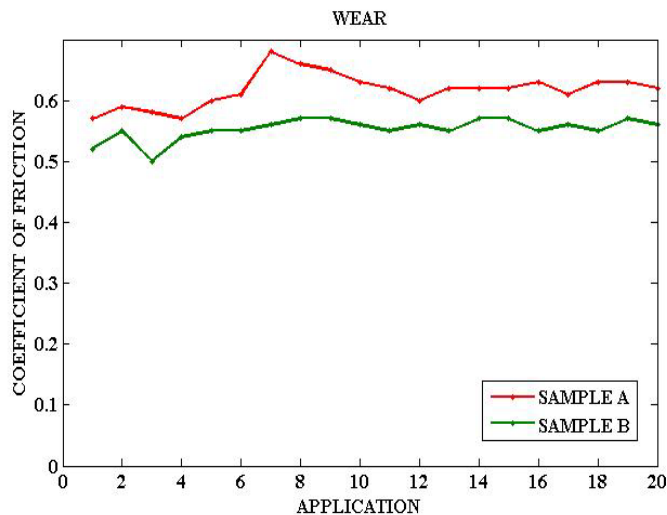


Figure 10: Plot comparison between the samples in wear.

in Figure 10. The coefficient of friction is consistent for both the samples. After ten applications, it depicts that wear is higher for sample B and picks up at later cycle. As in the case of sample A frictional stability is better to the latter. In Table 6 the wear characteristics shown for the 20 allocations. From the overall allocations the frictional value starts from nominal value and increases in a gradual scale for both the samples. In

the sample A frictional value resulted is higher compared to the sample B. It is evident that sample A shows the better wear characteristics.

Conclusion

This test results has shown the friction materials behavior of brake lining with comparison to different fillers materials in combination to

WEAR						
	Force-F		Load-N		μ	
	Samples					
	A	B	A	B	A	B
1	18.9	17.6	34.3	33.7	0.64	0.52
10	18.5	17.1	31	32.8	0.63	0.52
20	19.2	18.9	33.5	33.3	0.59	0.57

Table 6: Wear characteristics of both samples.

various operating test cycles in chase machine. From the test it is evident that sample A shows better frictional stability and wear characteristics, Also the temperature dependent behavior of the friction materials. With the addition of this filler materials the early presence of asbestos materials are now totally eradicated. Development of the friction material require significant amount of laboratory testing and on board vehicle testing. In future testing has to be performed with wide range of temperature and real time testing has to be done to know the actual life of the brake liner. The coefficient of friction what obtained in the chase machine is useful to judge the quality of the liner and to check the best formulation used. This case reveals only the critical value of friction; various operating conditions must be implemented in the computer controller to test the brake liners in the future.

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